METHODS FOR IMPLEMENTATING OPERATIONALLY-ORIENTED VULNERABILITY REQUIREMENTS FOR SHIPS, FOLLOW-ON

Charles N. Calvano, Associate Professor
Department of Mechanical Engineering
Sponsors: Office of the Secretary of Defense, Director of Operational Test and Evaluation, and Naval Postgraduate School

OBJECTIVE: To examine the feasibility of developing a methodology for the use of operationally-oriented vulnerability requirements (OOVRs) for ships which would: (1) keep decision makers informed, beginning early in the acquisition process, as to what weapon hits the ship must be capable of withstanding without sinking or losing the ability to continue to fight effectively and (2) establish requirements for ship designers in providing the passive protection necessary to achieve this capability.

SUMMARY: OSD has proposed the institution of operationally-oriented vulnerability requirements for ships. Operationally-oriented vulnerability requirements (OOVRs) would specify minimum levels of combat capability that must remain after a ship is hit by selected threat weapons likely to be encountered in combat. OOVRs would be expected to: (1) keep decision makers informed, beginning early in the acquisition process, as to what threats a ship must be capable of withstanding without sinking and while retaining the capability to fight effectively and (2) establish requirements for ship designers in reducing vulnerability as necessary to achieve this capability. This project will examine the feasibility of this type of requirement, give examples of the kinds of wording, formats, and measures that might be appropriate for such requirements and examine how the imposition of such requirements would affect the ship design and vulnerability assessment process. This task will be performed jointly with the Institute for Defense Analyses (IDA), which will take the lead.

CONFERENCE PRESENTATION:

Calvano, C., Reese, R., and Hopkins, T., "Operationally Oriented Vulnerability Requirements in the Ship Design Process," accepted for presentation at the Annual Meeting of the American Society of Naval Engineers (ASNE), 3 March 1998.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Surface Ship Survivability, Submarine Survivability, Vulnerability

RESEARCH AND DEVELOPMENT PLANNING FOR SURFACE SHIP SURVIVABILITY

Charles N. Calvano, Associate Professor
Department of Mechanical Engineering
Sponsor: Chief of Naval Operations

OBJECTIVE: To assist OPNAV in establishing a pilot effort to identify high pay-off technologies consistent with SC-21 mission goals and in assessing on-going initiatives and new areas of opportunity to help shape future core investments in ship survivability.

SUMMARY: In order to assist OPNAV in identifying high pay-off technologies consistent with SC-21 mission goals the principal investigator (PI) played a leading role in a workshop (which included participants from OPNAV, the Naval Sea Systems Command, the Naval Surface Warfare Center and other activities) at the U.S. Naval Academy during the week of 1/27/97. The PI's experience in ship design and ship survivability matters were valuable additions to the discussion and resulted in OPNAV establishing a ship survivability research center at NPS. Through continuing involvement with the workshop sponsor and through the OPNAV supported survivability research effort at NPS, Professor Calvano will continue to participate in Navy ship survivability improvement initiatives.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles – Ships and Watercraft

KEYWORDS: Surface Ship Survivability, Survivability, Ship Design, Vulnerability

ADVANCED TECHNOLOGY REVOLUTION IN MILITARY AFFAIRS (RMA) SHIP PLATFORM CONCEPTS

Charles N. Calvano, Associate Professor
Department of Mechanical Engineering
Sponsor: Navy Surface Warfare Center-Carderock Divison

OBJECTIVE: The Naval services want the ability to operate with impunity within enemy reach in littoral waters from affordable platforms capable of directing precision fires in support of a land campaign. Advanced operational concepts explored in the Revolution in Military Affairs (RMA) and developed by the CNO's Strategic Studies Group, (SSG), advanced weapons systems being investigated by CINCCENT and others, and advanced ship technologies developed by the Office of Naval Research and the Naval Surface Warfare Center, offer the promise of small ships with enhanced capabilities and survivability, and reduced operating costs. This program will explore innovative total ship approaches to improved Navy effectiveness.

SUMMARY: The SSG has postulated that U.S. Naval forces may gain operational flexibility and enjoy reduced vulnerability through an interconnected system of numerous functionally distributed, but physically dispersed, sensors and weapons. Emerging technologies make it feasible to consider seriously the physical dispersion, but functional joining, of ship assets. An inter-connected, advanced small ship, outfitted with cooperative engagement connectivity and the ability to control offboard sensors, complements the AEGIS/Blue Water ship team and advances the distributed concept one step further.

Such a ship could represent a major step in affordability and effectiveness and combine a very small crew with sufficient speed and endurance to transit to, and remain on station in, the desired theater of operations. Outfitted with a small number of advanced, precision-guided missiles capable of hitting precision and moving targets in the 20-100 km range, or with a weapon system capable of very rapidly firing a very large number of rounds in a shorter-range scenario, a small, highly-interconnected, inexpensive ship may represent a very effective and valuable addition to tomorrow's fleet. Professor Calvano is supporting this effort, along with Professor Hughes of the Department of Operations Research. Areas of exploration suggested by this initiative, include identification of missions and tasks for the ships, characterizing ships capable of those missions, and exploring the role of ship and combat systems modularity in making such ships more affordable and effective. This project involves the characterization of a mission capable small ship and evaluation of its ability to operate as a node in a distributed battlespace force architecture network and the evaluation of the operational concept of distributing weapons systems across a fully networked set of platforms in order to significantly improve the fleet's survivability. Professor Calvano is exploring the ship characterization and modularity aspects of this work with Professor Hughes addressing the missions and tasks.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles–Ships and Watercraft

KEYWORDS: Ship Survivability, Distributed Force, Fleet Survivability

EVALUATION OF DESIGNS FOR SEA-BASED DUAL BAND TRANSPORTABLE RADAR SHIP MODIFICATIONS

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F. A. Papoulias, Associate Professor
Department of Mechanical Engineering
Funding: U.S. Air Force-Hanscom Air Force Base

OBJECTIVE: The objective of this project was to assist the United States Air Force (USAF), Electronics Systems Center, in the pursuit of modifying a suitable hull form to function as a sea-based radar station.

SUMMARY: The T-AGOS class 3 and 4 ships are under consideration from the USAF for use as sea- based radar platforms. In order to meet mission requirements, their roll motion must be reduced. Several roll damping methods appropriate for these classes of ships were considered. Bilge roll stabilization was deemed as the most promising candidate for this problem and was studied in greater detail. Various sized bilge keels were analyzed utilizing a seakeeping prediction program for a full range of ship speed and sea states. Operability indices at several roll angles and for various bilge keel shapes were developed and compared. It was shown that operability improvement of up to a factor of two was possible. Design recommendations were made based on the results of this study.

OTHER:

Calvano, C.N. and Papoulias, F.A., "Evaluation of Designs for Sea-Based Dual Band Transportable Radar Ship Modifications," Final report to sponsor, April 1997.

THESIS DIRECTED:

Burdick, D. J., "Roll Stabilization for T-AGOS Class Ships," Master's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Ship Motions, Roll Stabilization

EVALUATION OF SIMSMART® SOFTWARE FOR USE IN SHIP PROGRESSIVE FLOODING PROBLEMS and ESTABLISHMENT OF A MODELING AND SIMULATION-BASED CENTER FOR TOTAL SHIP SURVIVABILITY STUDIES

Charles N. Calvano, Associate Professor
Department of Mechanical Engineering
Sponsors: Naval Surface Warfare Center-Carderock Division and the Chief of Naval Operations

OBJECTIVE: These two funded projects were closely related. The first evaluated the commercially available SIMSMART® software to determine its suitability for use in developing a design tool for considering surface ship progressive flooding and other damage conditions. It showed the desirability of entering into a Cooperative Research and Development Agreement (CRADA) with the company Advanced High Technology (AHT) which produces the software.

The second project involved identification of the resources necessary to begin to make use of the SIMSMART® software and other methods for conducting surface ship survivability research and the identification and purchase of the equipment and software necessary to establish a laboratory for these purposes.

SUMMARY: Professors Calvano and Papoulias visited the company and became familiar with the capabilities of the software, which was developed for use in designing and simulating fluid systems, such as refineries and breweries. It was determined that, with modification, the program showed promise as a tool in developing design algorithms and methods that could be used by Navy ship designers in evaluating the performance of their ship designs when subjected to damage and to progressive flooding. This became part of the basis for establishment of the Surface Ship Survivability Center and the beginning of an ongoing survivability research program at NPS under OPNAV sponsorship as well as the initiation of a CRADA with AHT. The software and hardware necessary to establish the research center were identified and purchased and are in place.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles–Ships and Watercraft

KEYWORDS: Surface Ship Survivability, Vulnerability, Progressive Flooding, Ship Design

AIR-TO-SURFACE AND SURFACE-TO-SURFACE TARGET ACQUISITION METHODOLOGIES

Morris Driels, Professor
Department of Mechanical Engineering
Sponsor: Joint Technical Coordinating Group, Surface-to-Surface Working Group

OBJECTIVE: To produce a target acquisition tool for attacking specific targets in known environments and terrain

SUMMARY: A computer tool was produced which enables operational users to specify the nature of the target they are attacking, the terrain in which the target is located and the cultural features surrounding the target. The tool then determines those sectors of approach that will be obstructed by, for example, surrounding buildings or specific terrain features. Given the location of the target in the world and the sensors used for detection, the tool provides users with target/background visible/thermal contrast values as a function of time of day. Finally, the tool superimposes acquisition, unmasks and delivers contours superimposed on imagery of the target area, and generates images of the target at the weapon release point. The program is applicable to airborne or ground based weapon systems used against ground targets.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Target Acquisition, Mission Planning, Weapon Effectiveness

TARGET ACQUISITION GUIDE UPDATE

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: Joint Technical Coordinating Group, Air-to-Surface Working Group and Naval Postgraduate School

OBJECTIVE: To computerize the current Joint Technology Coordinating Group (JTCG) target acquisition manual and to develop plans for its incorporation into the Joint Air-to-Surface Weaponeering System (JAWS)

SUMMARY: JTCG currently has a paper manual allowing users to predict the probability that a target they are planning to attack can be detected in sufficient time for the attacking aircraft to be maneuvered and the weapon released in time for a successful strike. The manual only contains data, and no algorithm, therefore, it cannot be updated for newly developed weapon systems and aircraft. The research involved discovering the underlying analytical basis for the data presented in the manual, updating this basis to reflect the latest available methodology, and encapsulating the results in a stand alone computer program to replace the current manual. This model was developed in FY97, and presented to the JTCG A/S community for their review and approval. Preliminary planning was done for the incorporation of this target acquisition module into JAWS, an FY98 task.

CONFERENCE PRESENTATION:

Driels, M., "JAWS Target Acquisition Model," JTCG Operational Users Working Group, Norfolk, VA, October 1997.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Target Acquisition, Mission Planning, Weapon Effectiveness

TARGET ACQUISITION MODEL EVALUATION

Morris Driels, Professor
Department of Mechanical Engineering
Sponsor: U.S. Army Training and Doctrine Analysis Command-Monterey

OBJECTIVE: To catalog and describe a selection of target acquisition models in support of the Joint ABCA (America, Britain, Canada, Australia) Quadripartite Task Force.

SUMMARY: In planning joint ground operations, each participant should use similar models for all phases of the operation in order to correctly predict the outcome of the action. In support of this the ABCA group has decided to adopt common models to estimate the outcome of certain forms of ground combat. In the area of target detection, standardized models will be needed in the areas of visual, infrared and video target observation, as well as models to predict observer search times and models of the human visual and cognitive systems. The research collated selected models in all of these areas, together with an analysis of those conditions in which the models are intended to perform. The resulting handbook allows users to evaluate and select appropriate models for the scenario under consideration, and to provide an analyst manual for that models operation

PUBLICATION:

Driels, M., "Handbook of Target Acquisition Models," Revision 1.2, December 1997.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Target Acquisition, Mission Planning, Combat Simulation

DEVELOPMENT OF DELPHI VISUAL PERFORMANCE MODEL

Morris Driels, Professor
Department of Mechanical Engineering
Sponsor: U.S. Army Training and Doctrine Analysis Command-Monterey

OBJECTIVE: To develop a visual performance model to predict surface-to-surface target detection tasks.

SUMMARY: The U.S. Army does not have a target detection model designed specifically for use in the visible spectrum. Instead, they use a model called ACQUIRE, which was developed solely for use in the infrared region, but has been adapted for the visible spectrum. ACQUIRE has been shown to be a poor predictor of performance in the visible spectrum for some scenarios. The United Kingdom has a very good visual performance model called ORACLE, but it is proprietary to British Aerospace. The research involves an analysis of the ORACLE model, and in particular if the algorithmic basis could be found in the open literature. If this could be done, a U.S. version of ORACLE (to be called DELPHI) could be developed and used. The result has been the development of a foveal optical channel which reproduces ORACLE's results with a high degree of accuracy. All algorithms have been obtained form public domain sources.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Target Acquisition, Visual Performance Models

CREEP OF FIBER REINFORCED METAL MATRIX COMPOSITES

I. Dutta, Associate Professor
Department of Mechanical Engineering
Sponsors: National Science Foundation and Naval Postgraduate School

OBJECTIVE: To investigate the mechanisms of creep in metal-matrix composites.

SUMMARY: The goal of this project is to develop a phenomenological understanding of the mechanisms operative during high temperature deformation of metal matrix composites reinforced by continuous fibers. A combination of experimental and analytical means are being utilized to develop a model for creep/ thermal cycling, with the eventual objective of generating transient deformation mechanism maps.

PUBLICATIONS:

Dutta, I. and Funn, J. E., "Creep Behavior of Interfaces in Fiber Reinforced Metal-Matrix Composites," submitted to *Acta Materialia.*

CONFERENCE PRESENTATIONS:

Dutta, I. and Funn, J. V., "Creep Behavior of the Interface Region in Continuous Fiber Reinforced Metal-Matrix Composites," 1997 TMS Fall Meeting, Indianapolis, IN, September 1997.

Dutta I. and Funn, J. V., "Creep Behavior of Interfaces in Fiber Reinforced Metal-Matrix Composites," invited paper at National Science Foundation Workshop on Composite Materials, Institute for Mechanics and Materials (UCSD), Ruidoso, NM, 5-8 October 1997.

THESES DIRECTED:

Funn, J. E., "Creep Behavior of the Interface Region in Continuous Fiber Reinforced Metal-Matrix Composites," Master's Thesis, Naval Postgraduate School, September 1997.

Esmele, II, M., "A Model for Deformation of Continuous Fiber Composites Under Isothermal Creep and Thermal Cycling Conditions," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Metal Matrix Composites, Creep/Thermal Cycling

PROCESSING AND FRACTURE OF PARTICULATE REINFORCED METAL-MATRIX COMPOSITES

I. Dutta, Associate Professor
Department of Mechanical Engineering
Sponsors: Army Research Office and Wright-Patterson Air Force Base

OBJECTIVE: To correlate processing, microstructure, and fracture properties in particulate reinforced aluminum (PRA) composites.

SUMMARY: The purpose of this project is to investigate microstructural development during processing of PRA, specifically with respect to the evolution of particulate distribution and matrix grain and precipitate structure, and to evaluate the

impact of fracture properties and mechanisms. The eventual goal is to design the material microstructure in such a way so as to result in substantially improved fracture toughness, while retaining the stiffness and strength advantage of PRA relative to unreinforced aluminum alloys.

PUBLICATION:

Dutta, I., Quiles, F.N., and McNelley, T.R., "Optimzation of the Fracture Behavior of a SiCp-6092 Al Composite via Control of Matrix Microstructure," *Metallurgical Transactions A*, in press.

CONFERENCE PRESENTATIONS:

Dutta, I., McNelley, T.R., Quiles, F.N., and Ballou, M.A., "Tailoring the Strength-Fracture Toughness Relation in Discontinuously Reinforced Aluminum Composites by Thermo-Mechanical Processing," presented at the 21st Annual Conference on Ceramics and Composites, Cocoa Beach, FL, January 1997.

McNelley, T.R. and Dutta, I., "Optimization of Strength and Fracture Toughness in Discontinuously Reinforced Aluminum Composites," Aeromat 97, Williamsburg, VA, 12 May 1997.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Particulate Reinforced Aluminum, Fracture Toughness, Unreinforced Aluminum Alloy

METALLIZATION OF CVD DIAMOND FOR ELECTRONIC PACKAGING

I. Dutta, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Warfare Center-Crane Division

OBJECTIVE: To develop approaches for metallization of CVD Diamond.

SUMMARY: The purpose of this project is to develop innovative approaches for producing adherent metallizations on CVD Diamond, which is an excellent thermal management material that is being currently considered for high-end electronic packages. Since metals do not naturally adhere to diamond, there is a need to develop new surface modifications for diamond to make metals stick to diamond.

PUBLICATION:

Menon, E.S.K. and Dutta, I., "Processing and Characterization of Aumina Thin Films on CVD Diamond Substrates for Producing Adherent Metallizations," *Journal of Materials Research*, 1997, in press.

CONFERENCE PRESENTATIONS:

Menon, E. S. K., Dutta, I., and Kroll, D. E., "Studies on Metallization of Surface Modified CVD Diamond Substrates for Electronics Packaging," 1997 MRS Fall Meeting, Boston, MA, 1-5 December 1997.

THESIS DIRECTED:

Kroll, D. E., "Metallization of CVD Diamond," Master's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Electronic Packaging, CVD Diamond

DIFFRACTION METHODS FOR THE ACCURATE MEASUREMENT OF STRUCTURE FACTORS AND CHARGE DENSITIES OF ELEMENTS AND INTERMETALLIC ALLOYS

A.G. Fox, Professor
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M. Saunders, National Research Council Postdoctoral Research Associate
Center for Material Sciences and Engineering
Department of Mechanical Engineering
Sponsors: Wright-Patterson Air Force Base, Naval Air Warfare Center-Patuxent River, and the Naval Postgraduate School

OBJECTIVE: To accurately measure the low-angle structure factors of elements and alloys by various diffraction methods so that their electronic bonding mechanisms can be investigated.

SUMMARY: A knowledge of the distribution of bonding electrons in crystalline solids can give important information about their physical properties. One way to gain such knowledge is to accurately measure the low-angle structure factors of the materials of interest by some means, and then use these to generate maps of the electron charge distributions. In the past both electron and x-ray diffraction were used to measure the low-angle structure factors of several elements and intermetallic alloys with high accuracy. The lattice parameters and Debye-Waller factors were measured by x-ray diffraction and the structure factors by the critical voltage technique in electron diffraction. More recently these measurements have been made using the energy filtering transmission electron microscope which has been recently installed at NPS. This has allowed NPS to fully quantify energy filtered convergent beam electron diffraction patterns and determine the low-angle structure factors of elements and alloys with an accuracy far greater than previously achieved and, in addition, it has been shown that it is possible to measure Debye-Waller factors by this method. This is leading to a vastly improved understanding of the nature of bonding in crystalline solids.

PUBLICATIONS:

Fox, A.G. and Menon, E.S.K., "Structure Factors and Bonding in NiAl," *Journal of Phase Equilibria*, Vol. 18, 509-516, 1997.

Fox, A.G., Menon, E.S.K., and Saunders, M., "Energy Filtered Imaging and Convergent Beam Electron Diffraction in the Transmission Electron Microscope," *Proceedings of the Microscopy and Analysis 1997*, pp. 973-974, Cleveland, OH, August 1997. (Invited)

Saunders, M., Fox, A.G., and Midgley, P.A., "Debye-Waller Factor Measurements by Quantitative Convergent Beam Electron Diffraction," *Proceedings of the Microscopy and Analysis 1997*, pp. 1011-1012, Cleveland, OH, August 1997.

Saunders, M., Fox, A.G., and Midgley, P.A., "Quantitative Convergent Beam Electron Diffraction; Measurements of Low Order Structure Factors of Nickel," *Proceedings of the Microscopy and Analysis 1997*, pp. 1013-1014, Cleveland, OH, August 1997.

Saunders, M. and Fox, A.G., "Quantitative CBED Measurements of Debye-Waller Factors in Metals," *Proceedings of the Electron Microscopy and Analysis Group 1997*, Cambridge, U.K., September 1997.

Saunders, M. and Fox, A.G., "Quantitative CBED Measurements of Low-Order Structure Factors in Metals," *Proceedings of the Electron Microscopy and Analysis Group 1997*, Cambridge, U.K., September 1997.

Saunders, M. and Fox, A.G., "Progress Towards the Full Quantification of Zone Axis Convergent Beam Electron Diffraction Patterns," *Proceedings of the International Centennial Symposium on the Electron*, Cambridge, U.K., September 1997.

CONFERENCE PRESENTATION

Fox, A.G. and Saunders, M., "Progress Towards the Full Quantification of Zone Axis Convergent Beam Electron Diffraction Patterns," an invited talk presented at Sagamore XII Conference, Waskesiu, Saskatchewan, Canada, July 1997.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Convergent Beam Electron Diffraction, Structure Factor Measurement, Bonding Charge Density

MICROSTRUCTURES AND MECHANICAL PROPERTIES OF HIGH-STRENGTH, LOW-ALLOY (HSLA) STEELS AND THEIR WELDMENTS

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M. Saunders, National Research Council Postdoctoral Research Associate
Center for Material Sciences and Engineering
Department of Mechanical Engineering
Sponsors: Naval Surface Warfare Center-Carderock Division, Office of Naval Research, in collaboration with the Naval Research Laboratory, and Naval Postgraduate School

OBJECTIVE: To investigate the microstructure and mechanical properties of ULC, HY and HSLA 80-130 series steels and their weldments to evaluate new weld consumables and parent steels for naval shipbuilding applications.

SUMMARY: In recent years the U.S. Navy has been replacing the HY80-100 series of high strength alloy steels with their high-strength, low-alloy (HSLA) equivalents. This is being done because the stringent weld pre-heat requirements associated with the HY steels are not necessary for the HSLA series. So, despite the higher manufacturing costs of high-strength, low-alloy steels, the U.S. Navy should make significant savings by changing over to HSLA or ultra low carbon (ULC) steels for ship and submarine construction. In order to extract the maximum benefit from these newly developed steels it is also necessary to develop improved weld filler wires. This project supports these objectives with fundamental physical metallurgy studies at NPS using advanced optical and electron microscopy techniques.

PUBLICATIONS:

Fox, A.G., Menon, E.S.K., and Saunders, M., "Energy Filtered Imaging and Convergent Beam Electron Diffraction in the Transmission Electron Microscope," *Proceedings of the Microscopy and Analysis 1997*, pp. 973-974, Cleveland, OH, August 1997. (Invited)

Menon, E.S.K., Reynolds, W.T., and Fox, A.G., "Electron Spectroscopic Investigations of the Solute Drag-Like Effect in Fe-C-Mo Alloys," *Proceedings of the Microscopy and Analysis 1997*, pp. 553-554, Cleveland, OH, August 1997.

Menon, E.S.K., Saunders, M., Fox, A.G., Reynolds, W.T., and Spanos, G., "PEELS of Steels," *Proceedings of the Electron Microscopy and Analysis Group 1997*, Cambridge, U.K., September 1997.

CONFERENCE PRESENTATIONS:

Fox, A.G., Menon, E.S.K., and Saunders, M., "Energy Filtered Imaging and Convergent Beam Electron Diffraction in the Transmission Electron Microscope," Microsopy and Analysis 1997, Cleveland, OH, August 1997. (Invited)

Menon, E.S.K., Reynolds, W.T., and Fox, A.G., "Electron Spectroscopic Investigations of the Solute Drag-Like Effect in Fe-C-Mo Alloys," Microscopy and Analysis 1997, Cleveland, OH, August 1997.

Menon, E.S.K., Saunders, M., Fox, A.G., Reynolds, W.T., and Spanos, G., "PEELS of Steels," Electron Microscopy and Analysis Group 1997, Cambridge, U.K., September 1997.

THESIS DIRECTED:

Greene, M.K., "The Effects of Titanium on the Mechanical Properties of Shielded Metal Arc Welding of C-Mn Steels," Master's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Ultra Low Carbon Steel, Welding

EVALUATION OF THE INFLUENCE OF WATER TEMPERATURE ON CRACKING IN UNDERWATER WET WELDS

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Center for Material Sciences and Engineering
Department of Mechanical Engineering
Sponsor: Naval Sea Systems Command

OBJECTIVE: To investigate the underbead cracking present in the heat affected zones of underwater shielded metal arc weldments.

SUMMARY: In recent years the U.S. Navy has been making a concerted effort to reduce maintenance costs, in particular the costs of dry docking. As a result, attempts are currently being made to underwater wet weld structural steels with carbon equivalents of 0.4 or less. Unfortunately, in fully restrained situations, it has proved difficult to produce such weldments without underbead cracking especially in low temperature water (less than 10 C). In this work fully restrained underwater wet welds are being produced on ASTM A516 Grade 70 steel under carefully controlled conditions at different temperatures. The microstructure and thermal history of these weldments is being carefully monitored in order that the precise mechanism of cracking can be understood.

THESES DIRECTED:

Johnson, R.L., "The Effect of Water Temperature on Underbead Cracking of Underwater Wet Weldments," Master's Thesis, Naval Postgraduate School, September 1997.

Dill, J.F., "Model for Estimation of Thermal History Produced by a Single Pass Underwater Wet Weld," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Underwater Wet Welding, Underbead Cracking

CHEMISTRY, MICROSTRUCTURE, AND DUCTILITY OF Ti-44Al-11Nb ALLOYS

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Center for Material Sciences and Engineering
Department of Mechanical Engineering
Sponsors: Naval Air Warfare Center-Patuxent River and the Naval Postgraduate School

OBJECTIVE: To investigate the microstructure of Ti-44Al-11Nb alloys by optical, scanning and transmission electron microscopies with a view to understanding the improved ductility that results from adding Nb toTiAl alloys.

SUMMARY: The overall objective of this research is to quantitatively correlate the microstructure and chemical composition of the various phases, the interfaces between them and the grain boundaries between like phases in a Ti-44Al-11Nb alloy in the as-processed condition using optical, scanning, and scanning transmission electron microscopies. In particular, the effects of alloying element segregation to grain boundaries and interfaces between different phases will be carefully studied. This includes oxygen and boron which are usually present in significant amounts in TiAl alloys and, since they are small atoms, they can rapidly segregate to grain boundaries and interfaces during processing. This analysis of the nature of microstructure, segregation, and interfaces in Ti-44Al-11Nb will hopefully allow an understanding of why Nb additions and certain processing conditions lead to improved ductilities in these alloy systems.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Ductility of Ti-Al-Nb Alloys, Optical and Electron Microscopy

QUANTITATIVE AND QUALITATIVE PEELS AND ENERGY DISPERSIVE X-RAY (EDX) SPECTROSCOPY USING THE NAVAL POSTGRADUATE SCHOOL TRANSMISSION ELECTRON MICROSCOPE

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R. Hashimoto, Materials Technician
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Department of Mechanical Engineering
Sponsors: Army Research Office, Wright-Patterson Airforce Base, Naval Surface Warfare Center-Carderock Division, Naval Air Warfare Center-Patuxent River, Naval Sea Systems Command, Office of Naval Research, and Naval Postgraduate School

OBJECTIVE: To investigate the capability of the NPS Topcon 002B transmission electron microscope (TEM) to perform both quantitative and qualitative parallel electron energy loss spectroscopy (PEELS) and energy dispersive x-ray (EDX) spectroscopy.

SUMMARY: Parallel electron energy loss spectroscopy (PEELS) and energy dispersive x-ray (EDX) spectroscopy are commonly used to obtain microchemical information in the transmission electron microscope (TEM). Indeed most of the TEM research carried out in the Center for Material Sciences and Engineering involves the use of PEELS or EDX to some extent. The center is finding that novel techniques for treating PEELS and EDX data, including the use of multivariate statistical analysis, can provide important chemical information about interfaces in multiphase systems. Recently an EMiSPEC vision system was installed on the Topcon 002B TEM and this will allow simultaneous acquisition of EDX and PEELS spectra to be made which will significantly improve the capability to perform quantitative EDX and PEELS.

PUBLICATIONS:

Hashimoto, R.Y., Menon, E.S.K., Saunders, M., and Fox, A.G., "Electron Energy Loss and Energy Dispersive X-ray Studies of Diffusion Bonded Cu-Al_2O_3 Interfaces," *Proceedings of the Microscopy and Analysis 1997*, pp. 993-994, Cleveland, OH, August 1997.

Hashimoto, R.Y., Menon, E.S.K., Saunders, M., and Fox, A.G., "Studies of Metal-Ceramic Interfaces by EDX and PEELS," *Proceedings of the Electron Microscopy and Analysis Group 1997*, Cambridge, U.K., September 1997.

Hashimoto, R.Y., Menon, E.S.K., Saunders, M., and Fox, A.G., "Analytical Electron Microscopy Studies of Cu-Al_2O_3 Interfaces," *Proceedings of the Metallurgical Society 1997 Fall Meeting*, Indianapolis, IN, September 1997.

CONFERENCE PRESENTATIONS:

Hashimoto, R.Y., Menon, E.S.K., Saunders, M., and Fox, A.G., "Electron Energy Loss and Energy Dispersive X-ray Studies of Diffusion Bonded Cu-Al_2O_3 Interfaces," Microscopy and Analysis 1997, Cleveland, OH, August 1997.

Hashimoto, R.Y., Menon, E.S.K., Saunders, M., and Fox, A.G. "Studies of Metal-Ceramic Interfaces by EDX and PEELS," Electron Microscopy and Analysis Group 1997, Cambridge, U.K., September 1997.

Hashimoto, R.Y., Menon, E.S.K., Saunders, M., and Fox, A.G., "Analytical Electron Microscopy Studies of Cu-Al_2O_3 Interfaces," Metallurgical Society 1997 Fall Meeting, Indianapolis, IN, September 1997.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Transmission Electron Microscopy, PEELS, EDX

THERMOACOUSTIC EFFECTS AT A SOLID-FLUID BOUNDARY: THE ROLE OF A SECOND ORDER THERMAL EXPANSION COEFFICIENT

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Department of Mechanical Engineering
Sponsors: National Aeronautics and Space Administration-Lewis Research Center and Naval Postgraduate School

OBJECTIVE: To conduct fundamental material and transport studies on thermoacoustic phenomena in microgravity with future application to thermodynamic engines aboard the Space Station.

SUMMARY: An analytical study has been conducted of the thermoacoustic effects induced by the interaction of a strong acoustic field with a rigid boundary such as that in a thermoacoustic engine. With the sphere as a representative object, it has been found that the acoustic field can create a spatially periodic heating and cooling pattern on its surface just as in the stack of a thermoacoustic engine. The thermoacoustic effects are generated primarily in the narrow Stokes boundary layer region on the sphere and are diffused and convected over the remaining part of the fluid domain. The unexpected role of a second-order thermal expansion coefficient in this process is explained.

PUBLICATION:

Gopinath, A., "Thermoacoustic Streaming on a Rigid Sphere," *Journal of the Acoustical Society of America*, Vol. 101, No. 5, pt. 2, p. 3022, May 1997.

CONFERENCE PRESENTATIONS:

Gopinath, A., "Thermoacoustic Streaming on a Rigid Sphere," 133rd Meeting of the Acoustical Society of America, State College, PA, June 1997.

Gopinath, A., "Heat Transfer in Thermoacoustic Engines," 32nd National Heat Transfer Conference, Baltimore, MD, August 1997.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Modeling and Simulation, Other (Basic Science)

KEYWORDS: Thermoacoustics, Acoustic Streaming, Acoustic Levitation, Thermophysical Property Measurement, Thermodynamic Moduli, Oscillatory Flows, Asymptotic Techniques

ACOUSTIC STREAMING IN MICROGRAVITY: FLOW STABILITY AND HEAT TRANSFER ENHANCEMENT

Ashok Gopinath, Assistant Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration-Jet Propulsion Laboratory

OBJECTIVE: To conduct fundamental material and transport studies on the role of acoustic streaming in enhancing transport rates in microgravity with application to materials processing.

SUMMARY: Analytical studies have been conducted on the role of steady streaming in enhancing heat and mass transport rates in a zero-mean acoustic field under microgravity conditions. In particular the compressible flow situation has been considered for which the object in question in the acoustic field is non-compact. This requires a Helmholtz decomposition of the vector velocity field requiring the solution of both a velocity potential and a stream function. The streaming flow pattern indicates some unique features resulting from the nonlinear interaction of both the rotational and irrotational velocity fields. Some preliminary numerical studies (on steady flows) based on the spectral method have also been initiated with the goal of application to oscillatory flows.

THESES DIRECTED:

Akcan, Z., "Uniform Flow Past a Rigid Sphere by Spectral Numerical Methods," Master's Thesis, Naval Postgraduate School, March 1997.

Zeybek, B., "Numerical Simulation of Flow Induced by a Spinning Sphere Using Spectral Methods," Master's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREA: Other (Energy Systems)

KEYWORDS: Acoustic Streaming, Heat Transport, Asymptotic Techniques

ACOUSTIC MODELING OF HYDRODYNAMIC WAVE LOADING

Ashok Gopinath, Assistant Professor
Department of Mechanical Engineering
Sponsor: Naval Postgraduate School

OBJECTIVE: To be able to use acoustics to simulate oscillatory wave loading on marine offshore structures.

SUMMARY: An experimental study was conducted to measure the forces on a cylinder in a standing acoustic field. The cylinder is representative of the leg of an offshore structure or platform, while the acoustic field is representative of the oscillatory wave loading on such a structure. The working fluid is high pressure nitrogen so chosen to reduce the viscosity to allow high values of the Reynolds number to be achieved. Both in-line (drag) and transverse (lift) coefficients have been measured and corroborated with existing data in the literature. The experimental technique appears to have promising potential for extension to larger values of the parameter regime which need further study.

PUBLICATION:

Gopinath, A. and Sweany, G.W., "Acoustic Modeling of Oscillatory Hydrodynamic Loading and Fluid-Structure Interaction," *Journal of the Acoustical Society of America*, Vol. 102, No. 5, pt. 2, p. 3066, November 1997.

CONFERENCE PRESENTATION:

Gopinath, A. and Sweany, G.W., "Acoustic Modeling of Oscillatory Hydrodynamic Loading and Fluid-Structure Interaction," 134th Meeting of the Acoustical Society of America, San Diego, CA, December 1997

THESIS DIRECTED:

Sweany, G.W., "Experimental Study of Oscillatory Flow Forces on Smooth Circular Cylinders in a Pressurized Acoustic Chamber," Master's Thesis, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Modeling and Simulation, Other (Basic Science)

KEYWORDS: Hydrodynamic Loading, Fluid-Structure Interaction, Acoustics, Reynolds Number, Lift and Drag, Offshore Marine Structures, Oscillatory Wave Loading

INTEGRAL EQUATION FORMULATION FOR LOCALLY NONLINEAR TRANSIENT STRUCTURAL SYNTHESIS

Joshua H. Gordis, Associate Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: This project is concerned with the theoretical development and computational implementation of a time domain theory for locally nonlinear transient structural synthesis.

SUMMARY: This research concerns the development of a time domain theory for structural synthesis. This new theory provides the previously unavailable capability of performing exact damped transient structural synthesis for systems with localized nonlinear components with the order of the synthesis being independent of model size. The method is based on Volterra integral equations derived from the convolution integral which describe substructure coupling and structural modification. Current results demonstrate an order of magnitude reduction in compute times as compared with widely-used commercial finite element analysis packages.

PUBLICATIONS:

Florence, D. E. and Gordis, J. H., "Time and Frequency Domain Synthesis in the Optimal Design of Shock and Vibration Isolation for Large Structural Systems," *Proceedings of the 68th Shock and Vibration Symposium,* Baltimore, MD, November 1997.

Florence, D.E. and Gordis, J.H., "Time and Frequency Domain Synthesis in the Optimal Design of Shock and Vibration Isolation for Large Structural Systems," submitted to *Shock and Vibration*.

Gordis, J.H. and Radwick, J.L., "Efficient Transient Analysis for Large Locally Nonlinear Structures," *Proceedings of the 68th Shock and Vibration Symposium*, Baltimore, MD, November 1997.

Gordis, J.H. and Radwick, J.L., "Efficient Transient Analysis for Large Locally Nonlinear Structures," submitted to *Shock and Vibration*.

CONFERENCE PRESENTATIONS:

Florence, D. E. and Gordis, J. H., "Time and Frequency Domain Synthesis in the Optimal Design of Shock and Vibration Isolation for Large Structural Systems," 68th Shock and Vibration Symposium, Baltimore, MD, 3-7 November 1997.

Gordis, J. H. and Radwick, J. L., "Efficient Transient Analysis for Large Locally Nonlinear Structures," 68th Shock and Vibration Symposium, Baltimore, MD, 3-7 November 1997.

THESIS DIRECTED:

Florence, D., "Time and Frequency Domain Synthesis in the Optimal Design of Shock and Vibration Isolation for Large Structural Systems," Engineer's Thesis, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Structural Dynamics, Transient Response, Synthesis, Nonlinear Dynamics

STRUCTURAL DYNAMICS OF THE RAH-66 COMANCHE HELICOPTER

Joshua H. Gordis, Associate Professor
Department of Mechanical Engineering
E. Roberts Wood, Professor
Department of Aeronautics and Astronautics
Don Danielson, Professor
Department of Mathematics
Sponsors: U. S. Army Aviation and Technology Command and the Naval Postgraduate School

OBJECTIVE: Technical support is provided to the U.S. Army Aviation and Technology Command, St. Louis, for the structural dynamics and vibration of the RAH-66 Comanche.

SUMMARY: The RAH-66 Comanche helicopter is the U.S. Army's attack helicopter for the 21st Century. During 1995, the Comanche began a program of ground vibration and flight tests, intended to validate structural dynamic performance of the airframe and to demonstrate the helicopter's performance characteristics. These tests typically uncover dynamics problems with rotor-fuselage coupling and forced response. In order to ensure the survival of the Comanche program, these problems, when discovered, must be quickly resolved. This effort provides rapid technical support to the Comanche Program, to resolve structural dynamics problems. FY97 efforts yielded the development of aft fuselage design modifications which were shown to increase torsional stiffness by 18%.

OTHER:

Wood, E. R., Danielson, D. A., and Gordis, J. H., "Research in the Structural Dynamic Response of the RAH-66 Comanche Helicopter," 1997 Report submitted to Comanche Program Manager's Office.

THESES DIRECTED:

Tobin, V., "Analysis of Potential Structural Design Modifications for the Tail Section of the RAH-66 Comanche Helicopter," Master's Thesis, Naval Postgraduate School, June 1997.

Shoop, B., "Structural Design Analysis of the Tail Landing Gear Bay and the Vertical/Horizontal Stabilizers of the RAH-66 Comanche Helicopter," Master's Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Helicopter, Comanche, Structural Dynamics

BUGS: BASIC UNEXPLODED ORDNANCE (UXO) GATHERING SYSTEM-MODELING AND SIMULATION

A.J. Healey, Professor
J. Kim, Research Assistant
Department of Mechanical Engineering
Sponsor: Naval Ordnance Technical Center

OBJECTIVE: This work is being undertaken to provide a modeling and simulation capability for evaluating the clearance performance of multiple cooperating vehicles in UXO gathering and minefield operations. The work involves the development and the evaluation of various robot system control concepts as proposed for the BUGS system and shallow water minefield reconnaissance/neutralization missions.

SUMMARY: The graphics simulator code runs on a high end SGI workstation currently. An ONYX reality engine workstation and has been developed using the "inventor" and "performer" tool kit. It is planned to use the simulator and its complementary modeling tools to evaluate sensor technology as well as control methodologies in relation to the performance of the overall BUGS system concepts for land-based ordnance clearance operations.

The simulator is built around a terrain base taken from the Marine Corps 29 Palms facility and a small subset of that database has been selected as a test site for evaluation of clearance operations. Vegetation has been included as uniformly distributed randomly dispersed objects added to the database. Munitions simulated include Mk 118 anti-personnel mines, and "softball" and "baseball" munitions that would have been dispensed from an airborne canister. These munitions are randomly distributed around a nominal center with an average density, selectable by the user.

Clearance operations are then simulated by a fleet of vehicles (BUGS) that can be controlled to a speed, heading and altitude above ground command. Walking machines are rendered as full kinematically faithful hexapods walking with a double tripod fixed gait, where each bug has an arm (boom) to support a camera, tactile, or magnetic sensor. The sensor has a defined radius of detection so that if a munition is encountered, a command is registered in the machine controller to manipulate the boom and retrieve the object.

Search patterns can be simulated that direct exhaustive searches if motion sensors are presumed to have sufficient accuracy for navigation to way points, or random searches if no navigation sensors are presumed to be available. The characteristics of random versus exhaustive search including obstacle avoidance have been established as part of this research, and the influence of various levels of navigation sensor accuracy and "inter-bug communication" on search effectiveness are being sought. Recently, questions concerning the comparison of random search as opposed to supervised autonomous directed searches for both PUCA and minefield operations are being analyzed. The effectiveness of obstacle avoidance methodology, path planning, and autonomous map building techniques, and the comparison of wheeled and tracked vehicle locomotion methods are being studied.

Four scenarios have been studied in detail. These are: (1) a field of distributed UXO being cleared by a fleet of robots; (2) particular vehicle behaviors moving around obstacles of large relative size to model experiments conducted at Indian Head, MD; (3) minefield neutralization scenarios for beach assault; and (4) clearing an MLRS site with an elliptical distribution of UXO using directed search coupled with local area spiral searching.

PUBLICATIONS:

Healey, A.J., Kim, Y., and Lewis, T., "Control of Small Robotic Vehicles in Unexploded Ordnance Clearance," *Proceedings of the IEEE ICRA 97*, Albuquerque, NM, April 1997.

Healey, A.J. and Kim, J., "BUGS: Robot Control, UXO and Minefield Clearance," Naval Postgraduate School Technical Report, NPS-ME-96-005, December 1996 (Available in 1997).

THESIS DIRECTED:

Starr, J., "Control of Small Robotic Vehicles for Mine Counter Measures," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Mine Warfare)

KEYWORDS: Robotics, Simulation and Modeling, Mine Warfare

STUDIES IN INTELLIGENT CONTROL OF AUTONOMOUS VEHICLES

A. J. Healey, Professor
Department of Mechanical Engineering
Sponsor: Ford Motor Company

OBJECTIVE: This grant is in the support of research in the subject matter without restriction, and serves to aid the ongoing programs in the Center for Autonomous Underwater Vehicle Research.

DoD KEY TECHNOLOGY AREAS: Other (Robotics, Underwater Vehicles)

KEYWORDS: Autonomous Systems, Robotics, Vehicles, Navigation

NAVIGATION OF REMOTE PLATFORMS

A. J. Healey, Professor
Department of Mechanical Engineering
Sponsor: Florida Atlantic University

OBJECTIVE: This project is aimed at a cooperative study between NPS and Florida Atlantic University (FAU) with the purpose of developing theories and algorithms for the asynchronous data fusion of Autonomous Underwater Vehicles (AUV) navigation sensory information.

SUMMARY: New navigation algorithms are needed for small AUV systems as they are limited in size and cost. Low cost sensor suites are less accurate than their higher cost counterparts, and their sensory data arrive at times that are not necessarily synchronized at control loop rates. With the new capabilities of networked embedded microprocessor systems, system control may be dispersed leading to distributed intelligent nodes that are capable of performing local area control functions coordinated by a higher level node. Sensory data arrive at arbitrary times when processed. For example, differential global position system (DGPS) position data arrives at approximately 1 second intervals. Acoustic doppler sonar returns when bottom locked, give information at about 2 Hz. Magnetic compass and inertial sensors for rotational rate may be available at high rates.

This work has developed a model-based navigation filter to smooth position and state estimates between updates using new data from all sensors as available. Bias and scale factor errors are included in the model and learned through the fusion of disparate sensors and compensated if constant.

Real-time implementation in the QNX operating system on an embedded pentium processor (with connectivity to Lon Works network protocols) as used by the FAU Ocean Voyager II AUV has been used to provide real time computability of the algorithms. It has been shown that filter computations are easily managed within the typical rates required for AUV navigation. Further real-time implementation work into the FAU vehicles remains.

PUBLICATIONS:

An, P. E., Healey, A. J., Park, J., and Smith, S. M., "Asynchronous Data Fusion for AUV Navigation Via Heuristic Fuzzy Filtering Techniques," *Proceedings of IEEE, Oceans 97*, Halifax, Canada, IEEE CD-ROM 0-7803-4111-2, October 1997.

Smith, S.M., Healey, A.J., McPhail, S., and Russel, R., "Lon Talk as a Standard Protocol for Underwater Sensor Platforms," *Proceedings IEEE, Oceans 97*, Halifax, Canada, 7 IEEE CD-ROM 0-7803-4111-2, October 1997.

Sur, J. and Healey, A. J., "Asynchronous Multi-Sensor Fusion for AUV Navigation," *Proceedings of COSU '97*, Vol. 2, pp. 321–332, Singapore, 12-14 May 1997.

Yun, X., Bachman, E., McGhee, R., Whalen, R., Roberts, Knapp, Healey, A., and Zyda, M., "Testing and Evaluation of an Integrated GPS/INS System for Small AUV Navigation," *Proceedings of the 10th Symposium on Unmanned Untethered Submersible Technology*, UUST, pp. 101-108, Durham, NH, 7-10 September 1997.

THESES DIRECTED:

Thorne, R., "Asynchronous Data Fusion for AUV Navigation Using Extended Kalman Filtering," Naval Postgraduate School Technical Report, NPS-ME-97-003, and Master's Thesis, Naval Postgraduate School, March 1997.

Sur, J., "State Observer for Linear Systems with Quantized Outputs," Doctor of Philosophy, Dissertation, University of California Santa Barbara, June 1996.

DoD KEY TECHNOLOGY AREAS: Other (Robotics and Automation, Underwater Vehicles, Mine Countermeasures)

KEYWORDS: Autonomous Systems, Robotics, Vehicles, Navigation

CONTROL ARCHITECTURES AND NON-LINEAR CONTROLLERS FOR UNMANNED UNDERWATER VEHICLES

A. J. Healey, Professor
Department of Mechanical Engineering
Sponsors: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: This project is funded through the Office of Naval Research (ONR) to jointly collaborate with researchers from Florida Atlantic University (FAU) and Virginia Polytechnic Institute (VPI) as part of a Multi University Research Initiative to seek enhancements in robustness in control systems of interest to the Navy. Robustness will be sought through multi-level hierarchical control schemes using robust nonlinear servo control laws at the lowest level and discrete state switching using elastic constraint and fuzzy reasoning at higher levels.

SUMMARY: The work is just starting and collaborative discussions are ongoing between VPI, FAU and NPS. The review of available simulation and modeling tools for unmanned underwater vehicles (UUV) applications is beginning. Not only are existing simulation tools being evaluated, but others used for both lower level servo control development such as MATLAB/SIMULINK but higher level simulation tools for the design of discrete state controllers using Petri Net methods and Finite State Machine simulators are being evaluated.

Robust nonlinear control methodology is expected to be used for ships underway replenishment, and at- sea transfer operations improvements, power electronic building block (PEBBS) systems, as well as for UUV and other underwater systems.

Building on robust control theory, this work has led to methodology for the automatic detection of subsystem faults arising from items such as control fin jams, or fin loss. Detection of faults is accomplished by a combination of model-free and model-based methods using both sensor information as well as the analytical redundancy afforded by the model-based filters.

PUBLICATIONS:

Riedel, J.S. and Healey, A.J., "A Discrete Filter for the Forward Prediction of Sea Wave Effects," *Proceedings of the 10th Symposium on Unmanned Untethered Submersible Technology*, UUST pp. 160-169, Durham, NH, 7-10 September 1997.

Silvestre, C., Pascoal, A., and Healey, A. J., "AUV Control Under Wave Disturbances," *Proceedings of the 10th Symposium on Unmanned Untethered Submersible Technology*, UUST, pp. 228-239, Durham, NH, 7-10 September 1997.

THESIS DIRECTED:

Simmons, A., "A Discrete Digital Filter for Forward Prediction of Seaway Elevation Response," Master's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREAS: Other (Robotics and Automation, Underwater Vehicles, Control)

KEYWORDS: Autonomous Systems, Robotics, Vehicles, Nonlinear and Robust Control

AUTOMATIC FAULT DETECTION AND CONTROL RECONFIGURATION

A. J. Healey, Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research

OBJECTIVE: Long term deployments of autonomous systems in the ocean require replenishment of energy supplies and reliable, fault free operation.

SUMMARY: It is recognized that fault free operation will not always be possible, so that system design must pay attention to a study of failure modes and their effects. In spite of the use of good engineering practice, faults can occur. Two kinds of "faults" identified are: 1) those that arise from malfunctions in the hardware and software subsystems in the vehicle and 2) those that arise from environmental conditions that are viewed as disturbances, and while these may not be directly "faults," they have the effect that the completion of a mission is jeopardized.

An example of a hardware fault would be the loss of steering resulting from a stuck or loose fin. An example of a type 2 fault would be the inability of the vehicle to take a data measurement because of high sea state in shallow water operation.

To design a system that will automatically detect the presence of a "fault" is the subject of many papers. This problem is common to the aircraft, spacecraft, and process industries, and much has been written about methods available. In general, methods can be classified into those that use simple limits and trends analysis, those that use detection techniques but which are without the use of analytical models, and those that provide analytical models as the basis for detection filters. The detection of status signals such as battery voltage, motor winding temperature, computer bay temperatures, is relatively easy and accomplished by the comparison of the measured signal with a previously set threshold. Exceeding those thresholds indicates a fault condition for which some action is taken—for instance either to slow down the vehicle speed or to abort the mission and surface. The detection of dynamic signal faults is more complex and requires the design of specially constructed residual generators, and is the subject of this activity. Special application to the U.S. Navy's 21UUV vehicle is implied.

PUBLICATION:

Humi, M. A., " Development of an On-Line Failure Mode Detection and Resolution Algorithm for the Phoenix AUV," Naval Postgraduate School Technical Report, NPS-ME-97-001, March 1997.

THESIS DIRECTED:

Humi, M. A., " Development of an On-Line Failure Mode Detection and Resolution Algorithm for the Phoenix AUV," Master's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREAS: Other (Robotics, Autonomous Systems)

KEYWORDS: Autonomous Systems, Robotics, Vehicles, Navigation

MODELING OF FIRE PROPAGATION IN MISSILE MAGAZINE SYSTEMS ON SURFACE COMBATANTS

Matthew D. Kelleher, Professor
Department of Mechanical Engineering
Sponsors: Naval Air Warfare Center-Weapons Division and Naval Postgraduate School

OBJECTIVE: The objective of this proposed work is to model the effects of fire on the thermal environment of missiles in the launch systems of surface combatant ships. Distributed lumped capacitance and thermal resistance models have been formulated to obtain time response behavior of a missile in a canister within a cell in the concentric canister launcher (CCL) system. More detailed computational fluid dynamics models of the fire induced environment within the systems is also being used to determine the effects on the missile of fire in the vicinity of and within the missile magazines. It is very important that an understanding of the propagation of fires in the various missile magazines be developed and that some means be developed to apply that understanding to the design of future combatants and to the development of fire fighting procedures.

SUMMARY: The thermal effects in the CCL due to a fire in an adjacent compartment have been simulated using computational fluid dynamics. A commercial code developed by CFD Research Corporation (CFDRC) has been used to implement the process. A model has been developed for the A-module, configuration of the CCL. Two fire scenarios are applied to the aft bulkhead of the launcher. The first scenario is indicative of a high temperature fire caused by burning missile propellent such as that experienced by the *USS STARK* (FFG-31). The second fire scenario simulates the conditions caused by burning diesel fuel from a ruptured shipboard F-76 fuel tank. For both scenarios, the model has been used to predict the time and location of the critical cook-off temperatures of the missile's propellents in the CCL.

THESIS DIRECTED:

Null, G.L., "Computer Simulation of the Thermal Effects on a Concentric Canister Missile Launcher with a Fire in an Adjacent Compartment," Engineer's Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Fire Propagation, Ship Survivability, Damage Control, Missile Magazines

EVALUATION OF ENVIRONMENTAL REQUIREMENTS, TEST METHODS AND STANDARDS FOR TACTICAL ADVANCED COMPUTERS: TEMPERATURE, HUMIDITY, AND OTHER ENVIRONMENTAL EFFECTS

Matthew D. Kelleher, Professor
Department of Mechanical Engineering
Sponsor: Space and Naval Warfare Systems Center-San Diego

OBJECTIVE: The objective of this work is to evaluate the Military Standards (MIL-STDs) for the protection against ambient and battle conditions for racks, cabinets, enclosures, and other components to be procured under the next phase of the Tactical Advanced Computer procurement. The areas investigated include the MIL-STDs pertaining to temperature, humidity, and other environmental effects.

SUMMARY: The environmental requirements for Tactical Advanced Computers as given in the TAC-5 Draft Request for Procurement have been compared to similar requirements for commercial equipment as addressed in various commercial standards such as IEEE Standard 1156.1-1993. An analysis and computer simulation of the thermal performance of the TAC-4 Rugged Rack (CLIN 0003AA) is being performed. A methodology for determining the effect of air flow through the rack system on the temperature of critical components mounted in the rack, including the processor, the power distribution unit (PDU), the monitor, and the uninterruptable power supply (UPS) is being developed. The model will be used to perform parametric studies accounting for convection and conduction cooling. The effect of fan capacity and ambient cooling air temperature will be evaluated.

DoD KEY TECHNOLOGY AREA: Other (Environmental Requirements)

KEYWORDS: Temperature and Humidity, Environmental Requirements, Tactical Advanced Computers

MODELING AND SIMULATION OF DAMAGE AND CRACKS IN SOLID ROCKET PROPELLANT MATERIALS

Young W. Kwon, Associate Professor
Department of Mechanical Engineering
Sponsor: U.S. Air Force-Phillips Laboratory and the Naval Postgraduate School

OBJECTIVE: This is a continuing project from previous years. The main study for this year was investigation of the effects of strain rates on the damage initiation and growth in a particulate composite with stress concentration.

SUMMARY: The micro/macromechanical approach was utilized, which was based on the interaction between a simplified micromodel and the finite element analysis technique. Continuum damage mechanics was applied to the microlevel analysis to model and simulate damage initiation and growth. Because the binder matrix material in the solid rocket propellant has a viscous material behavior, the applied loading rate affects the material behavior of the solid rocket propellant, especially its damage initiation and growth. The propellant material under study showed an increase in stiffness and strength as the applied loading rate increased. The numerical simulation showed that the damage initiation occurred at the lower applied strain level for the higher loading rate than for the lower loading rate. This was the same for both uniform and perforated plates subject to uniformly applied strains along the edges. At the early damage stage, the damage growth rate (damage growth per applied strain) was quite the same for the specimens under the high and low loading rates. However, as the damage grew further, the damage growth rate was slower for the higher loading rate case. Therefore, damage saturation occurred at the larger applied strain for the higher loading case. In terms of the physical time for damage saturation (i.e., failure), the higher loading case failed earlier. For the element just at the notch tip, the difference in the applied strain level where damage initiated, was smaller than the difference in the applied strain level when the damage saturates. For the

perforated specimen, the lower rate loading resulted in a larger saturated damage zone ahead of the notch tip.

PUBLICATIONS:

Kwon, Y.W., Lee, J.H., and Liu, C.T., "Modeling and Simulation of Crack Initiation and Growth in Particulate Composites," *Transactions of the ASME, Journal of Pressure Vessel Technology*, Vol. 119, No. 3, pp. 319-324, August 1997.

Kwon, Y.W. and Liu, C.T., "Study of Damage Evolution in Composites Using Damage Mechanics and Micromechanics," *Composite Structures*, Vol. 38, No. 1-4, pp. 133-139, 1997.

Kwon, Y.W. and Berner, J.M., "Matrix Damage Analysis of Fibrous Composites: Effects of Thermal Residual Stresses and Layer Sequences," *Computers and Structures,* Vol. 64, No. 1-4, pp. 375-382, 1977.

Kwon, Y.W. and Kim, C., "Micromechanical Model for Thermal Analysis of Particulate Composites," *Thermal Stresses '97*, pp. 37-40, Rochester, NY, 8-11 June 1997.

Kwon, Y.W. and Liu, C.T., "Effect of Strain Rate on Damage Evolution in Particulate Composites," *Proceedings of the Fourth International Conference on Composites Engineering,* pp. 573-574, Kona, HI, 6-12 June 1997.

Kwon, Y.W., Kim, C., and Yang, G.Y., "A Unified Micromodel for Constitutive Behavior of Metal Matrix Composites Undergoing Plastic Deformation," *Composites and Functionally Graded Materials,* ASME MD-Vol. 80, pp. 117-129, 1997.

Kwon, Y.W. and Liu, C.T., "Effects of Loading Rates on Damage Initiation and Growth in a Particulate Composite with a Viscoelastic Matrix Material," *Recent Advances in Solids/Structures and Application of Metallic Materials-1997,* ASME PVP Vol. 369, pp. 11-17, 1997.

Kwon, Y.W. and Kim, C., "Progressive Damage Evaluation of Composite Structures Using Micro/Macromechanics and Damage Mechanics," *Proceedings of the 14th U.S. Army Symposium on Solid Mechanics*, pp. 157-164, 1997.

Kwon, Y.W. and Kim, C., "Micromechanical Model for Thermal Analysis of Particulate and Fibrous Composites," *Journal of Thermal Stresses*, accepted for publication.

Kwon, Y.W., Lee, J.H., and Liu, C.T., "Study of Damage and Crack in Particulate Composites," *Composites, Part B: Engineering*, accepted for publication.

Kwon, Y.W. and Baron, D.T., "Numerical Predictions of Progressive Damage Evolution in Particulate Composites," *Journal of Reinforced Plastics and Composites,* accepted for publication.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Modeling and Simulation

KEYWORDS: Damage and Crack, Particulate Composite, Solid Rocket Propellant, Micromechanics, Finite Element Method, Strain Rate Effect

BIOMECHANICAL STUDY OF THE HUMAN KNEE MOTION WITH INTACT, INJURED, AND RECONSTRUCTED CRUCIATE LIGAMENTS

Young W. Kwon, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Medical Center

OBJECTIVE: This was a continuing project from previous years to understand the knee kinematics before and after ligament injury as well as after ligament reconstruction, and to evaluate different surgical techniques. This year's effort was

a mathematical modeling of the knee motions before and after the cruciate injury using the experimental data to find the instantaneous axis of rotation.

SUMMARY: The previously developed device was used to measure the knee motions from extension to flexion before and after the anterior cruciate ligament injury with data frequency of 15 Hz for rotations and translations. Kinematic constraint equations have been developed to analyze the six degree of freedom rotation and translational data to obtain an accurate approximation to the instantaneous axis of rotation. Four cadaveric knees were analyzed with all ligaments intact. Motion characteristics common to all knees were identified. The most obvious characteristics, internal tibial rotation, was related to the initial varus/valgus orientation of each knee. The anterior cruciate ligaments (ACL) of these same knees were subsequently served, the knees were measured, and the motion analyzed. Differences in the motion characteristics of each knee were detected after the ACL was cut.

PUBLICATION:

DeMaio, M., Adkison, D., Kwon, Y.W., Parks, S., Romero, N., and Bellen, R., "Continuous Motion Kinematics in the Loaded Human Cadaveric Knee: The Effect of Constraint, Axis, and Cruciate Transection and the Determination of the Instant Center of Motion," accepted for publication in *The American Journal of Sports Medicine.*

CONFERENCE PRESENTATION:

DeMaio, M., Adkison, D., Kwon, Y.W., Parks, S., Romero, N., and Bellen, R., "Continuous Motion Kinematics in the Loaded Human Cadaveric Knee: The Effect of Constraint, Axis, and Cruciate Transection and the Determination of the Instant Center of Motion," 23rd Annual Meeting of American Orthopedic Society of Sports Medicine, Sun Valley, ID, June 1997.

THESIS DIRECTED:

Parks, S. A., "Instantaneous Axis of Rotation for Continuous Human Knee Motion," Master's and Engineer's Thesis, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREA: Biomedical

KEYWORDS: Biomechanics, Knee Kinematics, Cruciate Ligaments, Instantaneous Axis of Rotation

BODY ARMOR AND INJURY PREVENTION: THE EFFECTS OF HELMETS AND ANTI-MINE FOOTWEAR ON INJURY

Young W. Kwon, Associate Professor
Department of Mechanical Engineering
Sponsor: Marine Corps Systems Command

OBJECTIVE: The goal of this project was to evaluate the counter-mine boots and over-boots against anti-personnel mines. As the first task, the mechanical properties of counter-mine boots and over-boots, which are currently available for U.S. soldiers, were evaluated. A preliminary finite element analysis was undertaken to evaluate the effectiveness of the boots for lower extremity injury.

SUMMARY: The sole of both boots were made of almost the same materials and the same layout of the materials. The used materials were a rubber, an aluminum honeycomb, a stainless steel, and a kevlar composite. The major structural strength and stiffness of the boots came from the aluminum honeycomb with stainless steel faceplates. All the materials used in the boots' soles were tested using an uniaxial testing machine to determine their mechanical properties like elastic moduli and ultimate strengths. Further, the scanning electron microscopy (SEM) was used for the stainless steel material to determine their chemical compositions. All the tests were conducted for multiple specimens to ensure their properties. In addition, a

preliminary finite element analysis was conducted to evaluate the counter-mine boot against an anti-personnel mine such as the M-14 mine.

PUBLICATION:

Muschek, R.C., King, Q.M., and Kwon, Y.W., "Evaluation of the Mechanical Properties of Countermine Boots," Naval Postgraduate School Technical Report, NPS-ME-97-007, November 1997.

DoD KEY TECHNOLOGY AREAS: Conventional Weapons, Modeling and Simulation

KEYWORDS: Body Armors, Mechanical Testing, Biomechanics, Finite Element Analysis

DYSMAS FOR PREDICTING UNDEX EFFECTS: SHIP SHOCK MODELING AND SIMULATION AND CONSTITUTIVE MODELING OF METALS

Young W. Kwon, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Warfare Center

OBJECTIVE: The goal of the research was to develop a new shell element which could model progressive failure of ship hulls subjected to underwater explosion.

SUMMARY: A shell formulation was developed from a three-dimensional solid. The shell element was an isoparametric element and had four corner nodes at which there were three displacements and three rotations, independently. Therefore, the element formulation included the transverse shear deformation and the transverse normal deformation. In addition, the formulation consisted of separate components of the mean stress and deviatoric stresses because the Gurson constitutive model for void growth is based on the mean stress and the dilatation. As a result, the Gurson void model could be implemented in the shell formulation at the next stage. The shell element used the reduced integration along the inplane axes and full integration along the transverse direction. If more accuracy were required along the thickness of the shell, a large number of integration points would be selected in the direction. Verification of the shell element was performed for a plate problem and a shell problem whose analytical solutions were available. The next phase of the work would implement the Gurson model into the shell element.

PUBLICATION:

Kwon, Y.W., "Development of a Shell Element with Pressure Variation Through Thickness," Naval Postgraduate School Technical Report, NPS-ME-97-006, September 1997.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Modeling and Simulation

KEYWORDS: Finite Element Analysis, Shell Element, Constitutive Equation for Microvoids

A NOVEL COATING TECHNIQUE TO ENHANCE STEAM CONDENSATION ON HORIZONTAL TUBES

P.J. Marto, Distinguished Professor Emeritus
Department of Mechanical Engineering
Sponsor: National Science Foundation

OBJECTIVE: The objective of this study was to investigate the effects of a self-assembled monolayer (SAM) coating on selective promotion of dropwise and filmwise condensation (DWC and FWC) regions on horizontal tubes. The scope included a parametric study to determine an optimum pattern of coexisting hydrophobic and hydrophilic regions to obtain

heat transfer enhancements exceeding a purely hydrophobic surface. In addition to the stated objectives, the study also included SAM coating on corrugated tubes, and on a variety of substrate materials spanning gold-coated aluminum, gold-coated titanium, copper and a copper-nickel.

SUMMARY: The hydrophilic SAM was found to be very unstable under filmwise condensing conditions, and hence the FWC zones were created by oxidizing the copper-tube surface. To do this, the hydrophobic zones were covered with a masking tape and the exposed zones were oxidized chemically. The mask was then removed and the un-oxidized surface was coated with the hydrophobic SAM to create DWC zones. A range of patterns with varying widths of DWC and FWC were successfully created by this technique.

While it was found that the SAM coating enhances DWC by a factor of ten under atmospheric conditions, and four under vacuum conditions, compared to FWC, the coexisting DWC-FWC patterns did not perform as well as expected. Within the scope of the patterns tested in this study, the maximum enhancement obtained with the patterns was only about eight under atmospheric conditions and 3.6 under vacuum, for a diamond-shape pattern with the widest FWC at the top of the tube. For the strip patterns, optimum enhancements were obtained for the 3mm DWC by 3mm FWC and 4mm DWC by 2mm FWC cases. Hence it is concluded that, for the patterns studied, a plain hydrophobic tube gives the best heat transfer enhancement, and that adding filmwise strips reduces the heat transfer more than it increases it due to reduced drop sizes in the DWC zones. Nevertheless, the SAM coating appears to be an extremely effective hydrophobic coating to enhance steam condensation heat transfer. Its use could make a significant reduction in condenser size.

This study also showed that SAM could very well be coated on a copper-nickel surface. So far, SAM coatings were believed to work only with gold, silver, and copper surfaces. The finding of this study greatly expands the application of SAM coating in the steam condenser industry where Cu-Ni is the commonly used material.

PUBLICATIONS:

Marto, P., "The Use of an Organic Monolayer Coating to Promote Dropwise Condensation of Steam on Horizontal Tubes," *Journal of Heat Transfer* (accepted for publication).

Marto, P., "Dropwise Condensation of Steam on Horizontal Corrugated Tubes Using an Organic Monolayer Coating," *Journal of Enhanced Heat Transfer* (accepted for publication).

Marto, P., "Co-existing Dropwise-Filmwise Condensation of Steam on Horizontal Tubes through a Self-Assembled-Monolayer Organic Coating," *International Journal of Heat Mass Transfer* (in preparation).

DoD KEY TECHNOLOGY AREA: Other (Steam Condensation on Horizontal Tubes)

KEYWORDS: Steam Condensation, Dropwise, Filmwise, Horizontal Tubes

GRAIN BOUNDARY CHARACTER AND SUPERPLASTICITY

T. R. McNelley, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: The goal of this program is to determine how boundary misorientation develops during deformation processing and the mechanisms by deformation microstructures may transform to a fine-grained superplastic state.

SUMMARY: Recently developed computer-aided electron microscopy diffraction analysis methods have been applied to the investigation of the mechanisms of grain boundary development during deformation processing and annealing of several superplastic aluminum alloys. Materials have been examined following various thermomechanical processing schedules and deformation histories. Aluminum alloys 5083, 7475 and laboratory-processed 2519 are observed to transform to a refined, superplastic microstructure via a primary (discontinuous) recrystallization reaction involving the formation and

migration of high-angle grain boundaries. However, Supral 2004, Al-10Mg-0.1Zr and Al-5Ca-5Zn materials transform by a continuous process. These different transformation processes may be distinguished by distinctly different grain boundary misorientation distributions. Primary recrystallization produces a random distribution similar to that predicted by Mackensie for randomly oriented cubes and the resultant superplastic response is often relatively limited. The continuous reaction results in a bi-modal misorientation distribution, with many moderately misoriented boundaries of misorientation near ten degrees, and a much more highly superplastic response.

PUBLICATIONS:

McNelley, T.R., McMahon, M.E., and Hales, S.J., "An EBSP Investigation of Alternate Microstructures for Superplasticity in Aluminum-Magnesium Alloys," *Scripta Materialia*, 36, pp. 369-375, 1997.

McNelley, T.R. and McMahon, M.E., "Application of EBSP Methods to Analyze Continuous Grain Refinement Processes in Supral 2004," *Proceedings of the ICSAM-97, International Conference on Superplasticity in Advanced Materials* (A. H. Chokshi, ed.), Materials Science Forum, Vols. 243-245, Trans Tech Publications, pp., 527–536, Zurich, Switzerland, 1997.

McNelley, T.R., McMahon, M.E. and Hales, S.J., "Grain Boundary Development Following Processing, Annealing and Deformation of Superplastic Aluminum Alloys," *Proceedings of the ReX'96: Third International Conference on Recrystallization and Related Phenomena* (T. R. McNelley, ed.), MIAS, pp. 519–525, 1997.

McNelley, T.R. and McMahon, M.E., "Microtexture and Grain Boundary Evolution during Microstructural Refinement Processes in Supral 2004," *Metallurgical and Materials Transactions A*, 28A, pp. 1879-1887, 1997.

Doherty, R.D., Hughes, D.A., Humphreys, F.J., Jonas, J.J., Jensen, D. J., Kassner, M.E., King, W.E., McNelley, T.R., McQueen, H.J., and Rollett, A.D., "Current Issues in Recrystallization: A Review," *Materials Science and Engineering*, A238, pp. 219-274, 1997.

Pérez-Prado, M.T., McNelley, T.R., Ruano, O.A., and González-Doncel, G., "Microtexture Evolution during Annealing and Superplastic Deformation," *Metallurgical and Materials Transactions A*, accepted for publication.

CONFERENCE PRESENTATIONS:

McNelly, T.R. and McMahon, M.E., "Application of EBSP Methods to Analyze Continuous Grain Refinement Processes in Supral 2004," ICSAM-97, International Conference on Superplasticity in Advanced Materials, Bangalore, India, 29 January 1997.

McNelley, T.R., Hales, S.J., and McMahon, M.E., "Microstructural Design for Improved Formability in Aluminum Alloys," AeroMat'97, Williamsburg, VA, 14 May 1997.

OTHER PRESENTATIONS:

McNelley, T.R. and McMahon, M.E., "Application of EBSP Analysis Methods to Grain Boundaries in Superplastic Al Alloys," at CTC Corporation, Johnstown, PA, 20 March 1997.

McNelley, T.R. and McMahon, M.E., "Application of EBSP Analysis Methods to Grain Boundaries in Superplastic Al Alloys," at NASA-Langley Research Center, Metallic Materials Branch, Hampton, VA, 12 May 1997.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Aluminum, Superplasticity, Recrystallization, Grain Boundaries, Thermomechanical Processing

A KNOWLEDGE-BASED APPROACH TO FRACTURE TOUGHNESS IMPROVEMENT VIA PROCESSING FOR PARTICULATE-REINFORCED ALUMINUM METAL MATRIX COMPOSITES

T.R. McNelley, Professor
Department of Mechanical Engineering
Sponsors: Army Research Office and Army Research Laboratory

OBJECTIVE: The goal of this program is obtain improved combinations of strength, ductility, and toughness in Al-based metal-matrix composite materials by thermomechanical processing.

SUMMARY: Discontinuously reinforced Al matrix composite materials have many attractive properties but lack adequate ductility and toughness for many applications. Dramatic improvements in composite ductility have been attained in extruded 6061 Al-Al_2O_3 processed using methods designed to redistribute the Al_2O_3 particles as well as achieve a fully recrystallized matrix grain structure via particle-stimulated nucleation of recrystallization. Further improvements in ductility have been obtained with use of controlled heat treatments on processed material. The influence of deformation temperature on redistribution of particles during processing has been investigated by controlled deformation of samples in a channel die. Fracture toughness improvements in extruded powder metallurgy 6092 Al-SiC material have been demonstrated and strength-toughness combinations equivalent to those of the unreinforced matrix alloy have been attained.

PUBLICATIONS:

McNelley, T.R., Ballou, M.A., and Dutta, I., "A Microstructural Investigation of Particle Redistribution during Thermomechanical Processing of a Cast 6061 Al - Al_2O_3 MMC," *Proceedings of the Symposium on Processing, Properties, and Applications of Cast Metal Matrix Composites* (P. K. Rohatgi, ed.), pp. 143–153, Warrendale, PA, 1997.

Dutta, I., Quiles, F.N., McNelley, T.R., and Nagarajan, R., "Optimization of the Strength-Fracture Toughness Relation in Particulate Reinforced Aluminum Composites via Control of Matrix Microstructure," *Metallurgical and Materials Transactions A,* in press.

PRESENTATIONS:

Dutta, I., McNelly, T.R., Quiles, F.N., and Ballou, M. A., "Tailoring the Strength-Fracture Toughness Relation in Discontinuously Reinforced Aluminum Composites by Thermomechanical Processing," 21st Annual Army Science Conference on Ceramics and Composites, Cocoa Beach, FL, 14 January 1997.

McNelley, T.R. and Dutta, I., "Optimization of the Strength and Fracture Toughness in Discontinuously Reinforced Aluminum Composites," AeroMat'97, Williamsburg, VA, 12 May 1997.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Metal-Matrix Composites, Processing, Particle Distribution, Fracture Toughness

METHODS FOR REDUCING LATERAL VIBRATIONS IN GAS TURBINES

Knox T. Millsaps, Assistant Professor
Department of Mechanical Engineering
Sponsors: Naval Sea Systems Command and Naval Postgraduate School

OBJECTIVE: To develop methods to reduce lateral vibrations in high speed turbomachines rotors.

SUMMARY: An analytical investigation was conducted to determine the physical mechanisms responsible for creating reduced response from an accelerating rotor. In particular, an analytical model was developed which models the long

slender rotor of an existing experimental facility. The transient model contains linear, direct and cross stiffness and damping which result from the bearing dynamics. The equations were integrated using time steps corresponding to constant angular phase rotation. The analytical predictions indicate that scheduling is more effective at high acceleration rates and the total transmitted power to the structure (noise) is more easily controlled than the displacement amplitude (stress).

PUBLICATIONS:

Millsaps, K.T. and Reed, G., " Reducing Lateral Vibrations of a Rotor Passing Through Critical Speed by Acceleration Scheduling," *Proceedings of IGTC,* Orlando, FL, 2-5 June 1997.

Millsaps, K.T. and Reed, G., "Reducing Lateral Vibrations of a Rotor Passing Through Critical Speed by Acceleration Scheduling," *Transactions of the ASME*, to appear July 1998.

Millsaps, K.T. and Bridges, C., "Reduction of Lateral Vibrations with Variable Accelerations," *ISOROMAC-7*, Honolulu, HI, 25-29 February 1998.

CONFERENCE PRESENTATIONS:

Millsaps, K.T. and Reed, G., " Reducing Lateral Vibrations of a Rotor Passing through Critical Speed by Acceleration Scheduling," *IGTC,* Orlando, FL, 2-5 June 1997.

Millsaps, K.T. and Bridges, C., "Reduction of Lateral Vibrations with Variable Accelerations," *ISOROMAC-7*, Honolulu, HI, 25-29 February 1998.

THESIS DIRECTED:

Bridges, C., "Analytical Investigation of a Simple Rotor with an Arbitrary Acceleration Schedule," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Rotordynamics, Accelerating Response, Acceleration Scheduling, Subcritical/Supercritical Transition

OPTIMIZING THE F-18 E/F FIRE SUPPRESSION SYSTEM

Knox T. Millsaps, Assistant Professor
Department of Mechanical Engineering
and
David W. Netzer, Distinguished Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center-Weapons Division

OBJECTIVE: To characterize the cooling flow field in the engine bay, between the engine and fuselage on the F/A-18 E/F, and to optimize the locations for fire suppressant injection.

SUMMARY: A low-speed, water tunnel flow visualization study was conducted on two subscale (6.2 to 1) models of the F/A 18-E/F cooling bays. Nitrogen bubble injection along with a laser sheet was used to visualize the flows at various cross-sections and hence to establish the baseline flow. Transient dye injections were made at various locations at the forward wall of the cooling bay. Videos were made to identify the mixing effectiveness due to injection at the various locations. Based on these observations, recommendations on the optimal locations for fire suppressant locations were made.

PUBLICATION:

Millsaps, K.T. and Netzer D. W., NAWCWPNS TM-8120, "F/A-18E/F Nacelle Ballistic Protection by Gas Generator Fire Suppression Systems," *Optimizing the F-18 E/F Fire Suppression System: Flow Visualization Study,* pp.37-50, September 1997.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles, Environmental Quality

KEYWORDS: Engine Cooling, Fire Suppression, Gas Generators, Halon Replacement

CONDITION-BASED MAINTENANCE FOR DIESEL ENGINES

Knox T. Millsaps, Assistant Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research

OBJECTIVE: To develop methods for determining cylinder firing pressure based on the instantaneous shaft speed.

SUMMARY: A torsional, dynamic engine model for a 3-cylinder, 2-stroke diesel engine was developed and calibrated. Measurements of near instantaneous shaft speed were made on a real engine for a wide range of applied torques and speeds. The model is capable of predicting shaft speed variations.

PUBLICATIONS:

Millsaps, K.T. and Bell, J. A., "Using Joint Time Frequency Distributions to Analyze Vibrations and Faults in a Diesel Engine," *Proceedings of SAE Congress*, Detroit, MI, 27-30 January 1997.

Millsaps, K.T., Bell, J.A., Hudson, J., and Swanson, W.A., "Development and Calibration of a High Fidelity Torsional Engine Model for a 3-Cylinder Diesel Engine," submitted for publication to *SAE*.

THESIS DIRECTED:

Hudson, J., "Development and Calibration of a Diesel Engine Torsional Model," Master's Thesis, Naval Postgraduate School, December 1997.

OTHER: Presentations given to NAVSEA03Z, Southwest Research and Ford Motor Company.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Sensors

KEYWORDS: Condition Based Maintenance, Diesel Engines, Cylinder Firing Pressure, Torsional Vibrations

DESIGN AND COLD FLOW VERIFICATION OF AN ENHANCED EDUCTOR FOR THE LOW OBSERVABLE MULTI-FUNCTION STACK (LOMFS) ADVANCED TECHNOLOGY DEMONSTRATION (ATD)

Knox T. Millsaps, Assistant Professor
Department of Mechanical Engineering
and
Garth V. Hobson, Associate Professor
Department of Aeronautics and Astronautics
Sponsors: Naval Surface Warfare Center-Carderock Division, Naval Sea Systems Command, and Office of Naval Research

OBJECTIVE: To develop and verify an enhanced mixing performance eductor design for the Low Observable Multi-Function Stack (LOMFS) Advanced Technology Demonstration (ATD). Also to provide consulting services as necessary to the ATD program.

SUMMARY: A 1-D fluid mechanical model was developed to predict the secondary flow and mixed-out temperature from an infrared suppressing, gas turbine ship exhaust eductor. The model was calibrated against DDG-51 baseline performance measurements. The model was used to perform parametric studies to optimize the performance of the new design. Preliminary facility design and component acquisition for a subscale, cold flow facility is underway. Consulting services and technical support were also provided to the program to measure the hot flow performance of the Phase I and Phase II Temeku Company eductor designs.

OTHER:

Millsaps, K.T. and Hobson, G.V., "Test Report and Analysis for the Temeku Cold Wall Eductor," submitted to NSWC-Carderock Division, 15 September 1997.

Millsaps, K.T., "Design Goals and Constraints for the LOMFS-ATD Eductor," submitted to NSWC-Carderock Division, 29 December 1997.

Millsaps, K. T., and Hobson, G.V., "Preliminary Design Report for the NPS LOMFS Eductor," to be submitted.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Surface/Under Surface Vehicles – Ships and Watercraft, Ground Vehicles

KEYWORDS: IR Signature Suppression, Ejectors, Eductors, Plume Temperature Reduction, Gas Turbine Exhausts

SYNCHRONOUS VIBRATIONS DRIVEN BY NON-UNIFORM TIP CLEARANCES IN AN AXIAL COMPRESSOR

Knox T. Millsaps, Assistant Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: To measure the time resolved pressure variations and induced synchronous forces due to rotating non-uniform tip clearances in an axial compressor.

SUMMARY: Time resolved pressure measurements were made over the rotor tips of a real compressor. Blade-to-blade and rotor speed variations were measured at several compressor speeds and flow coefficients and several geometries. Synchronous pressure forces (rotordynamic direct forces) were found and characterized.

PUBLICATIONS:

Millsaps, K.T. and Cuellar, A.F., "Prediction and Measurement of Synchronous Pressure Forces due to Non-Axisymmetric Tip Clearances," submitted for review to the IGTC, Stockholm, Sweden, 2-6 June 1998.

THESIS DIRECTED:

Cuellar, A.F., "Measurement of Synchronous Forces in an Axial Compressor," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Tip Clearances, Non-Uniform Compressor Flow, Synchronous Forces, Rotordynamic Forces.

EVALUATION OF SUBMARINE RESPONSE AND RECONFIGURATION CONTROL

F. A. Papoulias, Associate Professor
Department of Mechanical Engineering
Sponsors: Naval Surface Warfare Center-Carderock Division and the Naval Postgraduate School

OBJECTIVE: The objective of this project was to initiate efforts in characterizing and classifying submarine response and to develop strategies for reconfiguration control in cases of actuator or sensor failure and/or drastic changes of the environment.

SUMMARY: The objective of this work is the development of a control strategy which allows for on-the-fly reconfiguration of integrated guidance and control strategies of an underwater vehicle in shallow and littoral waters. In view of the uncertainties inherent in the littoral environment, an effective control strategy will need to monitor execution and modify plans on-line as needed. For this reason, an appropriate seamless integration of relevant planning, guidance and control functions is necessary. Recent efforts in artificial intelligence have addressed these issues and a number of suggested schemes focus on planning/control integration. A common feature of all schemes is the hierarchical integration of knowledge-based plans with reactive-type control laws while monitoring its performance. Although most architectures are formal within their computational domain, they tend to be rather ad-hoc when viewed from a systems viewpoint. A more formal approach to the integration of guidance and control functions in a shallow water environment is necessary for increasing system operability, performance, and mission success.

PUBLICATION:

Kang, W. and Papoulias, F.A., "Bifurcation and Normal Forms of Dive Plane Reversal of Submersible Vehicles," *Proceedings of the 7th International Offshore and Polar Engineering Conference*, Vol. II, pp. 62-69, Honolulu, HI, 25-30 May 1997.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Submarine Response, Guidance and Control, Reconfiguration Control

APPROXIMATION OF SHIP RIGHTING ENERGY USING PARAMETRICS

F. A. Papoulias, Associate Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: The objective of this project was to provide to NAVSEA OOC2 the capability to perform ship righting energy calculations from a parametric hull model.

SUMMARY: There currently exists no direct method for predicting the righting energy of a ship based on key geometric hull properties. Consequently, naval architects traditionally select hull parameters based on other constraints and merely check the dynamic stability indicators after designing the preliminary body plan. Quantifying these relationships would allow such indicators to be used as design variables in optimizing a hull form. Additionally, the hull form has a considerable impact on ship motions and dynamic stability criteria. The results of this work suggest possible functional relationships in order to predict the residuary stability of a design using basic hull parameters. A frigate and a tanker are used as candidate hull forms, although the methodology could be easily applied for a variety of hull types.

THESIS DIRECTED:

Sebastian, J.W., "Parametric Prediction of the Transverse Dynamic Stability of Ships," Master's Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Ship Stability, Righting Energy, Parametric Studies

AN EXPERIMENTAL AND NUMERICAL INVESTIGATION OF TURBULENT VORTEX BREAKDOWN AND AIRCRAFT WAKES

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration-Langley Research Center

OBJECTIVE: Basic and applied research towards the understanding of the phenomena resulting from the breakdown of vortices in trailing vortices and in a turbulent flow field, created by a round swirling jet issuing from a nozzle, for various swirl ratios, Froude and Reynolds numbers, and deep and shallow modes, using a three-component LDV system and laser-induced flow visualization.

SUMMARY: The statistical as well as structural characteristics of the turbulent flow field resulting from the swirling turbulent flow in a swirling jet in an unbounded medium were investigated in order to elucidate the physics of the phenomena relevant to the understanding of breakdown and its numerical simulation. Turbulence intensities, energy spectra, and turbulent stresses were measured with an LDV. The results refute the conjectures that the circumstances of breakdown are insensitive to the Reynolds number and the local turbulence properties.

PUBLICATIONS:

Sarpkaya, T. and Massidda, T., "Conductivity Measurements in the Wake of Submerged Bodies in Density-Stratified Media," *Proceedings of the Twenty-First Symposium on Naval Hydrodynamics*, Vol. 1, pp: 216-225, Trondheim, Norway, 1997.

Feyedelem, M.S. and Sarpkaya, T., "Free and Near-Free-Surface Swirling Turbulent Jets," *American Institute of Aeronautics and Aeronautics Journal* (to appear in the AIAA Journal, in March 1998).

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles – Ships and Watercraft

KEYWORDS: Vortex Breakdown, Vorticity, Swirling Flow, Free-Surface

KELVIN/LIGHTHILL POTENTIAL AND VORTICITY DRAG DECOMPOSITION OF WAVE LOADING

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research

OBJECTIVE: The scientific purpose of this continuing investigation is to carry out combined analytical, numerical, physical, and thought experiments to devise a physics-based model for the prediction of flow-induced unsteady forces on bluff bodies immersed in time-dependent flows. The new model, based on a sounder scientific rational, is expected to replace Morison's equation and offer greater universality and higher engineering reliability, particularly in the so-called drag-inertia regime.

SUMMARY: Over 3,000 digital force-time-data files have been evaluated during the second year of the continuing investigation in order to separate the resistance for each combination of the Keulegan-Carpenter number Kc, Frequency parameter b, the Reynolds number Re, and the relative roughness k_S/D into the sum of an inviscid inertial force and a vorticity-induced force. Several fundamental concepts for the modeling of the vorticity-force have been examined. After considerable effort, a new and relatively simple three-term force model has been devised.

PUBLICATIONS:

Sarpkaya, T., de Angelis, M, and Hanson, C., "Oscillating Turbulent Flow With or Without a Current About a Circular Cylinder," *Journal of Offshore Mechanics and Arctic Engineering*, TRANS. ASME, Vol. 119, pp. 73-78, May 1997.

Sarpkaya, T., "Resistance in Unsteady Flow–A New Physics Based Model," *Proceedings of the 22nd Symposium on Naval Hydrodynamics,* (in print, to appear in '98).

DoD KEY TECHNOLOGY AREA: Other (Fundamental Fluid Dynamics)

KEYWORDS: Bluff Body, Resistance, Unsteady Flows, Vorticity

DYNAMICS OF DROP FORMATION

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research and the Naval Postgraduate School

OBJECTIVE: To understand the physics of droplet formation, in general, and of the spray formation on bow-sheets, in particular, and devise means to minimize it in order to reduce the radar cross-section of ships and a number of other undesirable effects.

SUMMARY: An experimental investigation of the ligament and drop formation at the free surface of liquid wall jets, flowing over smooth and sand-roughened horizontal plates has been performed. Measurements were made with several high-speed imagers and analyzed through the use of appropriate software. The wall-jet Reynolds number ranged from 2.4×10^4 to 3.6×10^4, the Froude number from 19 to 27, and the Weber number from 1,500 to 3,000. Intersection of the turbulent boundary layer with the free surface, ligament and drop sizes, and the life-times of drops were determined from the digitized images and interpreted in terms of the characteristics of the turbulent boundary layer. The emphasis has been on the physics of the phenomenon rather than on the development of empirical relationships.

PUBLICATION:

Merrill, C.F. and Sarpkaya, T., "Spray Formation at the Free Surface of a Liquid Wall Jet," *American Institute of Aeronautics and Astronautics Paper,* No. 98-0442, 1977 (to appear in the AIAA Journal in 1998).

CONFERENCE PRESENTATION:

Merrill, C.F. and Sarpkaya, T., "Spray Formation at the Free Surface of a Liquid Wall Jet," 36th Aerospace Sciences of the American Institute of Aeronautics and Astronautics, Reno, NV, 12-15 January 1998.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Hydrodynamics, Drop Formation, Spray

THE STRUCTURE OF WAKE VORTICES MEASURED DURING THE MEMPHIS FIELD PROGRAM

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration-Langley Research Center

OBJECTIVE: To carry out an in-depth analysis of velocities, circulations, and decay histories of a number of trailing vortices generated by large aircraft during field tests in Memphis, TN, towards a clear understanding of the decay mechanisms. The interaction of vortices with what surrounds them and the relation between the full-scale flight tests and the physical/numerical laminar-flow experiments remain elusive because of the complex circumstances governing the pre-roll-up history and the post-roll-up state of the trailing vortices. Only some but not all of the governing parameters may be made to attain critically high enough values in small-scale physical and numerical experiments.

SUMMARY: The results suggest that field experiments are absolutely indispensable to create the conditions which sustain a critical damping mechanism. The decay of trailing vortices is governed by the mutual straining of vortices; intermittent exchange of mass, momentum, and vorticity across the core boundary; rotational damping and restructuring of turbulence in the core; stretching of large turbulent structures, turbulent diffusion, the interaction of oppositely-signed vorticity in the overlapping regions of the vortex pair, and the draining of vorticity from the Kelvin oval.

PUBLICATION:

Sarpkaya, T., "Decay of Wake Vortices of Large Aircraft," *American Institute of Aeronautics and Astronautics Paper,* No. 98-0442, 1997 (to appear in AIAA Journal in '98).

CONFERENCE PRESENTATION:

Sarpkaya, T., "Decay of Wake Vortices of Large Aircraft," 36th Aerospace Sciences Meeting of the American Institute of Aeronautics and Astronautics, Reno, NV, 12-15 January 1998.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles

KEYWORDS: Trailing Vortices, Vortex Decay, Wake Hazard

VORTEX BREAKDOWN IN TURBULENT SWIRLING FLOWS

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: National Science Foundation

OBJECTIVE: Trailing vortices, swirling flows in pipes, vortical flows above sweptback wings at large angles-of-attack, flows in closed containers with a rotating lid, and columnar vortices in atmosphere may experience breakdown: *The transformation of a slender vortex into three-dimensional forms*. Where, how, and under what circumstances does this transformation occur in *viscous* vortical flows constitute the essence of the breakdown problem.

SUMMARY: The mean velocities and turbulence intensities were measured in forward-scattering mode with a three-component Laser Doppler Anemometer. The results refute the conjectures that the circumstances of breakdown are insensitive to the Reynolds number and the local turbulence properties. These two factors have a strong influence on the evolution of the flow. Of all the known forms, the spiral emerges as the most fundamental breakdown form. All other forms may be regarded as transient states affected by various types of instabilities. At very high Reynolds numbers the breakdown acquires forms and characteristics never seen before: Extremely high rates of revolution, onset of core-bifurcation or core-trifurcation, intense nonisotropic turbulence, and a conical shape.

PUBLICATION:

Sarpkaya, T. and Novak, F., "Turbulent Vortex Breakdown: Experiments in Tubes at High Reynolds Numbers," Book Chapter in *Slender Vortices* (Ed: E. Kause), Kluwer Press, Berlin, pp. 1-8, 1997.

CONFERENCE PRESENTATION:

Sarpkaya, T. and Novak, F., "Turbulent Vortex Breakdown: Experiments in Tubes at High Reynolds Numbers," International Union of the Theoretical and Applied Mechanics Conference on Vortex Dynamics, Aachen, Germany, August 1997.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles

KEYWORDS: Vortex Breakdown, Vorticity, Swirling Flow

SHOCK AND VIBRATION RESEARCH IN SUPPORT OF ADVANCED LIGHTWEIGHT INFLUENCE SWEEP SYSTEM (ALISS)

Young S. Shin, Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Warfare Center-Carderock Division

OBJECTIVE: The scientific objectives include: (1) to study the operational environment in which the ALISS must be designed to perform and to make a recommendation on shock and vibration design criteria and (2) to investigate dynamic behavior of GA superconductor models and to assess the survivability based on the proposed shock and vibration design criteria.

SUMMARY: This is a on-going shock and vibration research project in support of advanced lightweight influence sweep system (ALISS). ALISS is an advanced technology demonstration (ATD) program to validate the feasibility of superconducting technology to sweep magnetic influence mines. A superconducting mine countermeasures (SCMCM) system would be small, light, and simple compared to currently deployed MCM system. When ALISS is constructed as a superconducting mine countermeasure, the system must perform satisfactorily under the extremes of shock and vibration environment encountered in military applications. The task conducted include: (1) modal analysis and transient response analysis of GA superconductor magnet SCMCM models and (2) to assess the shock and vibration survivability of the system.

PUBLICATION:

Lee, M. and Shin, Y. S., "Modal Analysis of a GA Superconducting Magnet Subsystem for ALISS," Naval Postgraduate School Technical Report, NPS-ME-97-004, April 1997.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: ALISS, Superconducting Mine Countermeasures, Light Weight Influence Mine Sweep System, Shock and Vibration

SHOCK AND VIBRATION ANALYSIS IN SUPPORT OF DDG-51 CLASS SHOCK FOLLOW-ON ACTIONS

Young S. Shin, Professor
Department of Mechanical Engineering
Sponsor: Naval Sea Systems Command

OBJECTIVE: To perform shock and vibration analysis in support of DDG-51 Class shock follow-on actions including DDG-51 Flight IIA ship shock analysis to predict dynamic responses of ship system and subsystem structures to underwater explosions.

SUMMARY: This task is a part of team project consisting of NAVSEA, NSWC, Electric Boat, Weindlinger Associates, Gibs & Cox, and NPS. The FY97-task was to conduct surface ship shock modeling and simulation of DDG-53. The task includes investigating whether the ship shock modeling and simulation can predict the dynamic transient responses of ship system and subsystem structures correctly. The analysis takes into accounts of the effects of the fluid-ship structure interaction and cavitation effects on a surface ship model (DDG-53) due to a large scale underwater explosion.

PUBLICATIONS:

Shin, Y.S. and Chisum, J.E., "Modeling and Simulation of Underwater Shock Problems Using a Coupled Lagrangian-Eulerian Analysis Approach," *Journal of Shock and Vibration*, Vol. 4 Issue 1, pp. 1-10, 1997.

Chisum, J.E., and Shin, Y.S., "Explosion Gas Bubble Near Simple Boundaries," *Journal of Shock and Vibration,* Vol. 4, Issue 1, pp. 11-26, 1997.

Shin, Y.S., and Santiago, L.D., "Surface Ship Shock Modeling and Simulation," *ASME Pressure Vessels and Piping,* Vol. 351, pp.29-34, 1997 ASME PVP Conference, Orlando, FL, 27-31 July 1997.

CONFERENCE PRESENTATION:

Shin, Y.S. and Santiago, L.D., "Surface Ship Shock Modeling and Simulation," 1997 ASME Pressure Vessels and Piping Conference, Orlando, FL, 27-31 July 1997.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation

KEYWORDS: Surface Ship, Underwater Explosion, Cavitation, Fluid-Structure Interaction

AGE-RELIABILITY ANALYSIS OF SHIPBOARD REPAIRABLE SYSTEMS

Young S. Shin, Professor
Department of Mechanical Engineering
Sponsor: Naval Sea Systems Command

OBJECTIVE: The objective is to examine whether certain class maintenance plan (CPM) tasks satisfy reliability centered maintenance (RCM) criteria for applicability for examining the age-reliability characteristics of one or more of three different shipboard equipments: AOE-1 Class main feed pumps, AOE-1 Class electric-driven fire pumps and controllers, and FFG-7 Class high-pressure air compressors.

SUMMARY: The age reliability relationships must be determined for an effective and efficient preventive maintenance (PM) program. New preventive maintenance requirements must be based on reliability centered maintenance (RCM) analysis as presented in MIL-STD-2173 (AS). A RCM analysis provides the reliability characteristics (mission reliability, probability of failure, age-reliability, etc.) on the equipment which may require age exploration. Ships' 3M data for the target equipment was obtained through the database maintained by Naval Sea Logistics Center. Five-year database contained over 8,000 repair records per target equipment. The statistical analysis has been conducted to develop age-reliability curve for FFG-7 Class high pressure air compressor (HPAC). The 17,400 repair records over five-year span were examined and the 1,400 records were selected as valid repair data to develop failure rate curve.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Age-Reliability, Ships' 3M Data, Repairable System

SURVIVABILITY OF SHIPBOARD PERSONNEL SUBJECTED TO HIGH AMPLITUDE, LOW FREQUENCY SHOCK INDUCED BY UNDERWATER EXPLOSION

Young S. Shin, Professor
Department of Mechanical Engineering
Sponsor: Naval Sea Systems Command

OBJECTIVE: Modeling and simulation of dynamic behavior of hybrid dummies mounted on the SSTV subjected to underwater explosion. The shock loading includes the high amplitude, low frequency shock. Subsequently the dynamic behavior of shipboard personnel (normal male and female) will be investigated from the standpoint of survivability and critical injuries.

SUMMARY: The articulated total body (ATB) modeling approach was used to model the motion of a human (or test dummy such as the Hybrid III) in response to ship shock. The preliminary investigation was conducted to simulate the response such as the gross motion, the contact forces between body parts and the surrounding environment, the torque within the body's joints, and the relative accelerations of the body parts (head acceleration with respect to the upper torso, for example).

PUBLICATION:

Oglesby, D.B. and Shin, Y.S., "Biodynamic Response of a Hybrid III Dummy and a Human Male to an Underwater Explosion Event," submitted to *Journal of Shock and Vibration.*

Oglesby, D.B. and Shin, Y.S., "Biodynamic Response of a Hybrid III Dummy and a Human Male to an Underwater Explosion Event," *Proceedings of the 68th Shock and Vibration Symposium* in CD-ROM, November 1997.

CONFERENCE PRESENTATION:

Oglesby, D. B. and Shin, Y. S., "Biodynamic Response of a Hybrid III Dummy and a Human Male to an Underwater Explosion Event," 68th Shock and Vibration Symposium, Hunt Valley, MD, 3-7 November 1997.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Underwater Explosion, Human Survivability

EVALUATION OF ENVIRONMENTAL REQUIREMENT, TEST METHODS AND STANDARD FOR TACTICAL ADVANCED COMPUTERS: SHOCK, NOISE, AND VIBRATION

Young S. Shin, Professor
Department of Mechanical Engineering
Sponsor: Space and Naval Warfare Systems Center-San Diego

OBJECTIVE: To review and evaluate the MILSPECS from the standpoints of shock and vibration for the survivability of racks, cabinets, enclosures and other components to be procured under TAC-5 (Tactical Advanced Computer Fifth Generation).

SUMMARY: The Navy has demonstrated a commitment to migrating highly customized automation requirements in tactical systems to approaches exploiting the use of commercial-based technologies and commercial-off-the-shelf (COTS) components as part of the TAC-5. However, the survivability of COTS in various types of severe environments is questionable. The evaluation results showed that the recent commercially available products such as high performance processors, low cost workstations, fully populated 72" and 60" racks may meet the code requirement for airborne noise, structureborne noise, storage and transportation shock, and ship motion and attitude. However, the COTS may not survive for severe shock and vibration environments.

PUBLICATION:

Oesterreich, M.H. and Shin, Y.S., "Modal Analysis of the 72 Inch TAC-4 Ruggedized Rack (CLIN 0003AA)," Naval Postgraduate School Technical Report, NPS-ME-97-005, September 1997.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Shock and vibration, TAC-5, Computers

FREQUENCY AND AMPLITUDE MODULATION APPROACH FOR MACHINERY NOISE AND VIBRATION SUPPRESSION

Young S. Shin, Professor
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Michael D. McClatchey
Office of Naval Intelligence
Sponsor: Office of Naval Intelligence

OBJECTIVE: The objective is to investigate the frequency modulation method to suppress machinery noise and vibration. It may be more practical and effective to shift machinery noise and vibration energy to a wide frequency range by the frequency modulation technique. The periodic/non-periodic variations of system variables (such as operating frequency) and system model configuration may be the key to redistribute the noise and vibration energy.

SUMMARY: Machinery noise and vibration suppression has been a major focus of the Russian Navy's ship silencing program for many years. Russian open source literature claims further noise reductions may be possible through frequency modulation of rotating machinery. The narrow-band noise level of rotating machinery (in particular, a submarine's main SSTG and associated components) may, therefore, be reduced by modulating the operating frequency. Two important factors influence the amount of noise and vibration reduction: (1) the sweep rate of the frequency modulation and (2) the bandwidth over which the frequency is distributed. This investigation determines the response, that is, how much and how quickly rotating machinery noise can be reduced by using this modulation technique.

THESIS DIRECTED:

McClatchey, M.D., "Noise and Vibration Suppression of Rotating Machinery by Frequency Modulation," Master's Thesis and Engineer's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Noise and Vibration, Suppression, Frequency Modulation